

Research Article

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Houses as Collateral and Household Debt Deleveraging in Korea

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Abstract: As Korea's household debt has increased rapidly since the mid-2000s, concerns that its economy's hard-wired leveraging may negatively impact economic activity have grown. Calls are being made for policy actions to return the economy to its long-run trend. Housing preferences and monetary shocks can both trigger deleveraging, as most household debt is profoundly connected to the housing market, and debt growth increases sensitivity to interest rates. Constructing a dynamic stochastic general equilibrium model with heterogeneous households and the housing production sector, we simulate and analyze the macroeconomic effects of deleveraging. Because a lower loan-to-value (LTV) ceiling limits the size of household debt, the deleveraging effect caused by borrowers' re-optimization is alleviated as the LTV ceiling decreases. When the housing price is included as an additional operating target in an otherwise standard monetary policy (MP) rule, economy-wide welfare increases when the MP is proactive to demand shocks and inactive to supply shocks. These findings suggest that deleveraging risk can be attenuated by adopting a lower LTV ceiling and maneuvering MP asymmetrically depending on the source of a shock.

Keywords: collateral, deleveraging, emerging economy, household debt, loan-to-value ceiling, monetary policy rule

JEL classification: E31, E52

1 Introduction

Korea is regarded as a leading and influential emerging economy and has unique real estate and housing markets

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characterized by the *Chonsei* system (Kim, Cho, & Ryu, 2018a, 2018b, 2019).¹ With potential buying pressure in the housing and asset markets and substantial borrowing demand due to *Chonsei* contracts,² Korea's household debt started increasing in the early 2000s and has continuously accumulated over the last 20 years. Because this debt has grown too quickly in Korea and is highly concentrated in the housing market, concerns are growing that underperformance in the housing market will trigger a domino effect of household debt deleveraging. This outcome would heavily impact both the stability of the real economy and the financial system. Household debt deleveraging is recognized as the single most serious risk over the last several years. Policymakers are aware of the potential issues that may arise from deleveraging and continuously warn that the market must limit housing-related lending.

In Korea, the growth rates of household debt and household income move in opposite directions. Figure 1 shows that the household credit growth rate, which fell below 2% in 2003, rapidly rose up to almost 12% in 2006 owing to an overheated real estate market. It then declined following the introduction of the debt-to-income ratio.

1 More details on the Korean economy and its microeconomic and macroeconomic characteristics, as a leading, representative market, are provided in the studies of Chun, Cho, and Ryu (2020), Chung, Cho, Ryu, and Ryu (2019), Kim, Batten, and Ryu (2020), Lee and Ryu (2019a, 2019b), Ryu, Kim, and Ryu (2019), Ryu, Ryu, and Yang (2020), Ryu, Webb, and Yu (2020), Ryu and Yu (2020, 2021), Seok, Cho, and Ryu (2020), Shim, Chung, and Ryu (2018), Song and Ryu (2016), and Yu and Ryu (2020, 2021).

2 The Korean economy is the only economy worldwide that supports the *Chonsei* system. *Chonsei* is considered a Korean-style residential real estate leasing contract. *Chonsei* can be viewed as a mortgage by tenants, not banks (Moon, 2018). A tenant taking a *Chonsei* contract normally pays an upfront deposit of about 50–80% of the market price depending on the housing conditions (Kim, 2017). Unlike typical housing rental systems in other countries, Korea's *Chonsei* system does not require the tenant to make periodic rental payments, and the tenant receives the nominal deposit amount back at the end of the *Chonsei* contract.

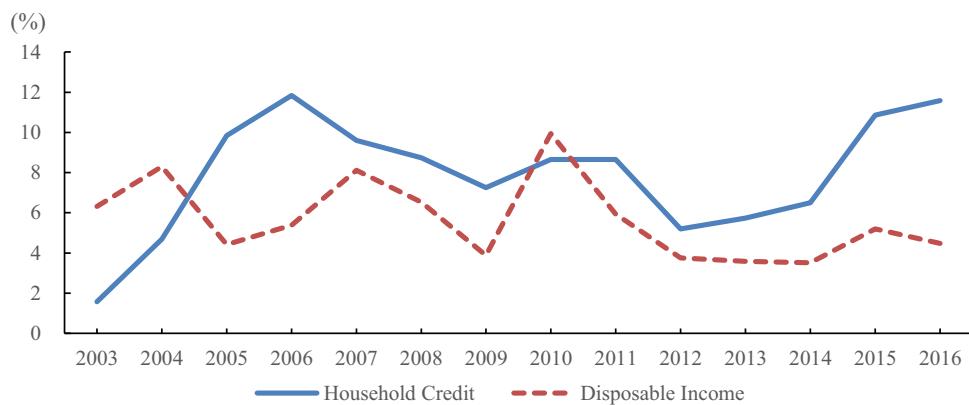


Figure 1: Growth rates of household credit and disposable income. Note: Household credit is composed of household loans and the sales credits of depositors and other financial institutions. Source: Bank of Korea.

This growth rate has rebounded since 2012. Disposable income grew at an annual rate of about 6% through 2011, but this growth rate has dropped to 4% since 2012. As a result, the ratio of household credit to disposable income has steadily increased from 58.7% in 2003 to 82.2% in 2016, with the exception of a dip in 2004, as shown in Figure 2.

Household debt deleveraging refers to the phenomenon in which the credit supply suddenly shrinks and debt sharply falls as financial institutions cease lending or refuse revolving loans. This decrease in lending is caused by a decline in the collateral value of debt households when asset prices fall owing to shocks caused by tightened lending regulations, interest rate hikes, and so forth. If household debt deteriorates owing to a decline in real estate prices and a rise in interest rates, then both the loan-to-value (LTV) ratio and the financial burden from interest payments increase accordingly. Owing to the high level of outstanding debt, households become more sensitive to interest rates, and financial institutions grow more reluctant to provide new loans and refuse to revolve existing debts, as they need to meet the LTV ratio ceiling set by the supervising authority. As debt-ridden households sell their houses, housing prices decline and the LTV ratio deteriorates further, creating a vicious cycle.³ When the government shifts to a policy of tightening to solve the household debt problem, the asset market collapses and the financial institutions' credit supply shrinks, reducing the households' capacity to

repay their debts and leaving many households insolvent. This vicious cycle, known as debt deflation, not only aggravates the macroeconomy but also increases the financial risk. The financial intermediary function is also likely to deteriorate as credit supply falls.

In theory, household debt can play either a positive or negative role depending on the state of the economy. On the positive side, borrowing for consumption or asset purchases increases total consumption and construction investments (Di Maggio et al., 2017; Seppecher & Salle, 2015). On the negative side, an excessively high level of household debt can reduce GDP by restricting the consumption of borrowers, who must service their debts, and reducing investment, as higher debt levels increase interest rates (Benigno, Eggertsson, & Romei, 2020; Cecchetti & Kharroubi, 2012; Cecchetti, Mohanty, & Zampolli, 2011; Law & Singh, 2014; Mian, Sufi, & Verner, 2017). Taken together, household debt can positively affect GDP in the short term, but it becomes a burden on the economy once it reaches a certain threshold. If the household debt exceeds this threshold, the negative effects offset the positive effects and eventually dominate the economy.⁴

Academics and policymakers have recently reached a consensus that the Korean economy is approaching the threshold rapidly. The subsequent discussions focus on

³ McKinsey Global Institute (2010) reports that it takes 6–7 years to overcome a financial crisis and that the debt-to-gross domestic product (GDP) ratio falls by 25% during this period.

⁴ Arcand, Berkes, and Panizza (2015) analyzed 120 countries from 1960 to 2010 and found that a debt-to-GDP ratio of 50% is the threshold for changing the growth effect of debt from positive to negative. However, Cecchetti et al. (2011) argued that this threshold is as high as 85%. Koo (2009) explained that a debt ratio above this threshold triggers a balance sheet recession, and the standard macroeconomic remedies cannot save the economy from a recession.

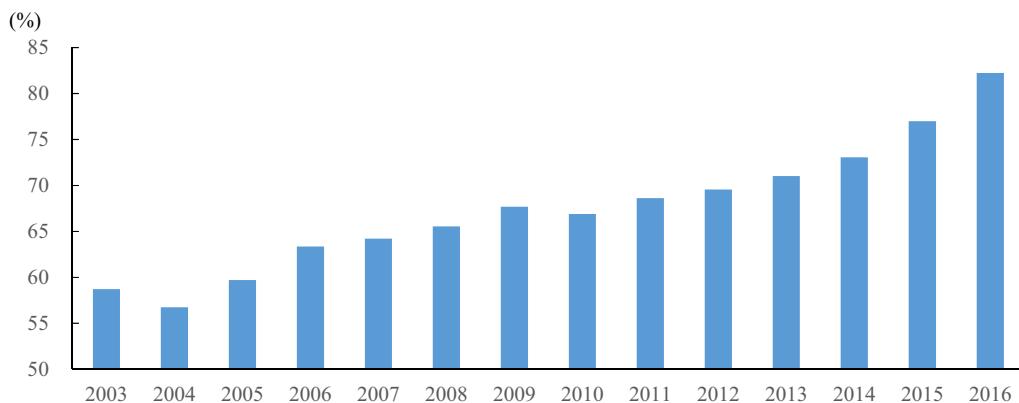


Figure 2: Ratio of household credit to disposable income. Source: Bank of Korea.

the timing, scope, and degree of the adverse effects of household debt and the introduction of policy measures to reduce the magnitudes of the negative impacts. Rising interest rates directly reduce consumption and investment, and the decline in lending to businesses and households due to asset price declines through financial accelerators further reduces consumption and investment. Importantly, these issues with household debt are related to the total debt stock rather than the increase or decrease in the stock at a particular time. An increase in interest rates affects not only newly issued debt but also the entire stock of outstanding debt (Cerutti & Claessens, 2017). When this stock is so large that households need to borrow more to pay the interest on their existing debts, the economy reaches a tipping point at which a flow problem becomes a stock problem. Thus, policies to keep the stock of debt from crossing this tipping point are the first line of defense to allow the economy to land softly during a deleveraging phase.

Previous studies on the relationships between the housing sector and economic variables can be divided into two categories: studies using vector autoregression (VAR) models and studies using dynamic stochastic general equilibrium (DSGE) models. Iacoviello (2005) presented a DSGE model with limited household borrowing up to a certain fraction of the house's value, i.e., an LTV ceiling. Since this seminal work, follow-up studies have been continuously conducted. Iacoviello and Neri (2010) extended Iacoviello's (2005) model to demonstrate the existence of spillover effects from the housing market to non-housing consumption. Guerrieri and Iacoviello (2017) solved a nonlinear version of Iacoviello's (2005) model. In the Korean market, Song (2008) analyzed the effects of macroeconomic factors on domestic housing prices using a dynamic factor VAR model and reports that national factors explain 78% of the total volatility

in housing prices. Lee and Song (2015) examined the relationship between real estate prices and key economic variables by constructing a DSGE model that includes the housing production sector, and they discuss the role of real estate in the Korean business cycle.

However, the previous DSGE models do not directly include real estate as an investment asset;⁵ instead, they treat it as a type of collateral to alleviate borrowing limits. In other words, real estate is treated as a vehicle for smoothing consumption, and the models include no explicit explanations of how real estate is produced and traded in the market. This study, in contrast, includes housing in the DSGE model to examine its investment and collateral roles. We also include heterogeneous households to see how differences in preferences affect the transmission of policy shocks and examine the economic impacts of household debt deleveraging triggered by a decline in real estate prices. This study also treats housing construction as a separate production sector to allow the housing supply to respond to housing prices. When the housing supply is exogenously given, changes in housing prices affect the economy only through incomes, as the housing supply cannot respond to housing prices. Thus, by allowing the housing market to adjust for housing prices, we can analyze the interactions among consumption, non-housing investments, monetary policy (MP), and housing in more detail. From a modeling standpoint, we primarily follow Iacoviello and Neri (2010), assuming that households have heterogeneous desires to save and collateral constraints to capture housing business cycles. Whereas Iacoviello and Neri (2010) discussed the economic fluctuations caused by housing investments and

⁵ For the wide use of DSGE models, refer to Gerali, Neri, Sessa, and Signoretti (2010) and Lindé (2018).

production in an economy with heterogeneous households, this study focuses on the effectiveness of central bank MPs that set borrowing restrictions, such as LTV ceilings, in the housing sector. This study also discusses whether a housing-price-adjusted MP rule is more effective under demand- or supply-driven shocks, which Iacoviello and Neri (2010) and other previous studies do not address.

This study compares the macroeconomic effects of deleveraging for different LTV ratio requirements and, thus, is similar to previous studies on the contribution of the leveraging and deleveraging cycles to the US economy. In particular, Justiniano, Primiceri, and Tambalotti (2015) concluded that exogenous shifts in collateral requirements are not the main driver of macroeconomic outcomes, and they challenge the perspective that an exogenous tightening of collateral requirements was the main trigger of households' deleveraging during the credit cycles in the early 2000s. Although the simulation results based on Korean data reconfirm the previous studies' insights and demonstrate muted macroeconomic consequences of looser LTV requirements, this study's goal and interests differ from those of previous studies. Whereas the previous study aims to identify the sources of the macroeconomic shocks driving booms and busts in the housing market, this study aims to assess the macroeconomic impact of shifts in LTV requirements and the welfare effects of MPs that react to housing market shocks. Furthermore, this study analyzes and compares two regimes with different LTV ceilings. Justiniano, Primiceri, and Tambalotti (2019) modeled patient and impatient households with borrowing and lending constraints and show that lending constraints were the key driver of the housing price boom in the US before the Great Recession. Whereas the previous studies investigate the interplay between borrowing and lending constraints in the housing price cycle, this study focuses on assessing the macroeconomic effects of tightening LTV ratio regulations according to the level of the LTV ceiling and on evaluating the effectiveness of an MP rule that responds to housing price shocks. This model also emphasizes that the LTV ratio requirement is the main independent cause of changes in household debt and that a shock to households' preferences for housing services has limited impacts on changes in housing prices and, thus, on household debt.

This study also contributes to the literature in that it relates to a recent experience in Korea. The developments in the Korean housing market during the analysis period (i.e., from the first quarter of 2000 to the second quarter of 2017) are similar to the situation in the US prior to 2007. After the burst of the information technology bubble in the

early 2000s, the US maintained low interest rates, and the demand for housing increased owing to the aggressive expansion of mortgage loans by banks, which started generating profits with private mortgage-backed securities. The first quarter of 2000 through the second quarter of 2017 is generally characterized by an upsurge in the Korean housing market, but the real housing price moderated or slightly decreased after 2008 owing to the global financial crisis and an aggressive housing supply driven by the Korean government at the time. However, the new administration, which took power in 2013, has maintained low interest rates, and housing prices have steadily risen as economic stimulus policies have increased the demand for real estate (Jang, Song, & Ahn, 2020). However, Korea is characterized by its unique *Chonsei* system, and its LTV and debt-to-income regulations are relatively strong, reflecting significant differences from the US prior to 2007. Korea's LTV ceiling reached a maximum of 70% within the analysis period, whereas the US government provides less regulation for overheated speculation, with a maximum LTV ceiling of more than 90% before the Great Recession (Zhang & Xu, 2020).

The rest of this article is organized as follows. Section 2 shows how a DSGE model that reflects stylized facts about household debt is constructed. Section 3 provides the calibration and estimation results of the model. Section 4 analyzes the dynamic effects of deleveraging by adjusting the LTV ratio and MP rules. Section 5 summarizes the main findings and presents conclusions.

2 Model

We assume that the economy has two types of households with different subjective time discount rates, as introduced by Iacoviello (2005) and Iacoviello and Neri (2010). The economy includes non-housing production, housing production, and central banks. Houses are constructed and supplied in the housing production sector, and households obtain utility from the consumption of housing services. The monetary authority controls the interest rate according to a Taylor-type MP. Unlike standard macroeconomic models, which include housing only in consumption, this study considers the housing production sector as a separate economic entity to determine the dynamic movement of housing prices along the equilibrium path. This assumption also allows us to examine the macroeconomic effect of the financial accelerator on housing.

We denote the two types of households in our model as $j = 1, 2$. These household types have different subjective discount factors (β_i , $i = 1, 2$), and the discount factor of type-1 households is greater than that of type-2 households, i.e., $\beta_1 > \beta_2$. The type-1 households are referred to as savers and the type-2 households are referred to as borrowers.

2.1 Savers

The savers solve the following utility maximization problem:

$$\max E_t \left[\sum_{\tau=0}^{\infty} \beta_1^{\tau} U(c_{1,i,t+\tau} - bc_{1,i,t+\tau-1}, h_{1,i,t+\tau}, l_{1,i,t+\tau}) \right], \quad (1)$$

where the utility function is defined as

$$U(c_{1,i,t} - bc_{1,i,t-1}, h_{1,i,t}, l_{1,i,t}) = e^{\zeta_{c,t}} (\ln(c_{1,i,t} - bc_{1,i,t-1}) + e^{\zeta_{h,t}} \chi_h \ln(h_{1,i,t}) - \chi_l l_{1,i,t}^2). \quad (2)$$

The savers' budget constraint is

$$\begin{aligned} c_{1,i,t} + \frac{P_{h,t}}{P_{s,t}} (h_{1,i,t} - (1 - \delta_h) h_{1,i,t-1}) + \frac{B_{1,i,t}}{P_{s,t}} + \frac{P_{n,t}}{P_{s,t}} n_{1,i,t} \\ \leq \frac{W_{1,i,t} l_{1,i,t}}{P_{s,t}} + \frac{R_{t-1} B_{1,i,t-1}}{P_{s,t}} + \frac{R_{n,t}}{P_{s,t}} n_{1,i,t} + \frac{P_{n,t}}{P_{s,t}} n_{1,i,t-1} \\ + \frac{T_{1,i,t}}{P_{s,t}}, \end{aligned} \quad (3)$$

where $c_{1,i,t}$ is consumption, $h_{1,i,t}$ is the housing stock, $l_{1,i,t}$ is labor hours, $B_{1,i,t}$ is nominal bond holding, $n_{1,i,t}$ is the supply of land, $T_{1,i,t}$ denotes transfers from the production sectors, $P_{s,t}$ is the price of standard goods, $P_{h,t}$ is the housing price, $P_{n,t}$ is the land price, $W_{1,i,t}$ is the nominal wage rate, R_t is the nominal interest rate, $R_{n,t}$ is the land rental rate, and δ_h is the housing depreciation rate.

Type-1 households own land and provide it to the housing production sector. In addition, $\zeta_{c,t}$ and $\zeta_{h,t}$ represent consumption preference and housing demand shocks, respectively. Housing preference shocks are economic shocks that affect the preference for buying a home, such as changes in property taxes, transaction taxes, or expectations that housing prices will rise. The parameter b represents the degree of consumption habits (Dynan, 2000); also χ_h and χ_l are the proportions of housing and leisure in the utility function, respectively.

As all savers behave the same way in the symmetric equilibrium, we drop the subscript i hereafter. We assume Calvo-type nominal wage rigidity. Households assume that their wages are adjusted with probability $1 - \theta_w$ or are adjusted only by the inflation rate π with probability

θ_w . Using the logarithmic linearization method, the New Keynesian wage Phillips curve is obtained as

$$\begin{aligned} \hat{\pi}_{1,t}^w = \beta_1 E_t [\hat{\pi}_{1,t+1}^w] + \frac{(1 - \theta_w)(1 - \beta_1 \theta_w)}{\theta_w(1 + \phi_l/(\phi_l - 1))} (\hat{l}_{1,t} - \hat{\lambda}_{1,t}^b) \\ - \hat{w}_{1,t} + \zeta_{c,t}), \end{aligned} \quad (4)$$

where $\pi_{1,t}^w$ is the wage inflation ($W_{1,t}/W_{1,t-1}$), $w_{1,t}$ is the real wage ($W_{1,t}/P_{s,t}$), $\lambda_{1,t}^b$ is the Lagrangian multiplier for the budget constraint, and ϕ_l is the wage markup parameter. Variables with a hat ($\hat{\cdot}$) are log-linearized. The first-order conditions for utility maximization are as follows:

$$\frac{e^{\zeta_{c,t}}}{c_{1,t} - bc_{1,t-1}} - \beta_1 b E_t \left[\frac{e^{\zeta_{c,t+1}}}{c_{1,t+1} - bc_{1,t}} \right] = \lambda_{1,t}^b, \quad (5)$$

$$\lambda_{1,t}^b = \beta_1 E_t \left[\lambda_{1,t+1}^b R_t \frac{P_{s,t}}{P_{s,t+1}} \right], \quad (6)$$

$$\frac{P_{h,t}}{P_{s,t}} \lambda_{1,t}^b = e^{\zeta_{c,t}} e^{\zeta_{h,t}} \frac{\chi_h}{h_{1,t}} + \beta_1 E_t \left[\frac{P_{h,t+1}}{P_{s,t+1}} (1 - \delta_h) \lambda_{1,t+1}^b \right], \quad (7)$$

$$\frac{P_{n,t}}{P_{s,t}} \lambda_{1,t}^b = \frac{R_{n,t}}{P_{s,t}} \lambda_{1,t}^b + \beta_1 E_t \left[\lambda_{1,t+1}^b \left(\frac{P_{n,t+1}}{P_{s,t+1}} \right) \right]. \quad (8)$$

2.2 Borrowers

Borrower households, which have a lower subjective hourly discount rate than saver households have, can see the effects of the financial accelerator due to housing price fluctuations and borrowing restrictions. These households borrow the necessary funds from savers. Borrowers solve the following utility maximization problem.

$$\max E_t \left[\sum_{\tau=0}^{\infty} \beta_2^{\tau} U(c_{2,t+\tau} - bc_{2,t+\tau-1}, h_{2,t+\tau}, l_{2,t+\tau}) \right], \quad (9)$$

subject to the budget constraint

$$\begin{aligned} c_{2,t} + \frac{P_{h,t}}{P_{s,t}} (h_{2,t} - (1 - \delta_h) h_{2,t-1}) + \frac{B_{2,t}}{P_{s,t}} \\ \leq \frac{W_{2,t} l_{2,t}}{P_{s,t}} + \frac{R_{t-1} B_{2,t-1}}{P_{s,t}}. \end{aligned} \quad (10)$$

In equilibrium, borrowers, unlike savers, do not hold shares of land or production firms. Borrowers face collateral constraints, such as those of Iacoviello (2005) and Iacoviello and Neri (2010).

$$-\frac{B_{2,t}}{P_{s,t}} \leq \Phi_2 E_t \left[\frac{P_{h,t+1}}{P_{s,t}} \frac{1}{R_t} (1 - \delta_h) h_{2,t} \right], \quad (11)$$

where Φ_2 is the average LTV ratio.⁶ We apply the same assumption on the rigidity of nominal wages as in the case of savers and find that the wage Phillips curve of borrowing households is given by

$$\hat{n}_{2,t}^w = \beta_2 E_t [\hat{n}_{2,t+1}^w] + \frac{(1 - \theta_w)(1 - \beta_2 \theta_w)}{\theta_w(1 + \phi_l/(\phi_l - 1))} (\hat{l}_{2,t} - \hat{\lambda}_{2,t}^b - \hat{w}_{2,t} + \zeta_{c,t}). \quad (12)$$

The first-order conditions for utility maximization are as follows:

$$\frac{e^{\zeta_{c,t}}}{c_{2,t} - bc_{2,t-1}} - \beta_2 b E_t \left[\frac{e^{\zeta_{c,t+1}}}{c_{2,t+1} - bc_{2,t}} \right] = \lambda_{2,t}^b. \quad (13)$$

$$\lambda_{2,t}^b = \beta_2 E_t \left[\lambda_{2,t+1}^b R_t \frac{P_{s,t}}{P_{s,t+1}} \right] + \lambda_{2,t}^c. \quad (14)$$

$$\begin{aligned} \frac{P_{h,t}}{P_{s,t}} \lambda_{2,t}^b &= e^{\zeta_{c,t}} e^{\zeta_{h,t}} \frac{X_h}{h_{2,t}} + \beta_2 E_t \left[\frac{P_{h,t+1}}{P_{s,t+1}} (1 - \delta_h) \lambda_{2,t+1}^b \right] \\ &+ \Phi_2 e^{\zeta_{\Phi_2,t}} \lambda_{2,t}^c E_t \left[\frac{P_{h,t+1}}{P_{s,t}} \right] \frac{1}{R_t} (1 - \delta_h), \end{aligned} \quad (15)$$

where $\lambda_{2,t}^c$ is a Lagrangian multiplier associated with the collateral constraint.

From the Euler equation of the saver households in the steady state, $R = \Pi/\beta_1$ should hold. By substituting this condition into the optimization problem for borrower households in the steady state, we can derive the following relation:

$$\lambda_2^c = \lambda_2^b \left(1 - \frac{\beta_2}{\beta_1} \right) > 0. \quad (16)$$

Thus, the borrowing constraint is binding in the steady state. We assume that the labor input in the production sector is a combination of labor from both savers and borrowers and takes the form:

$$l_t = \Xi_l (l_{1,t})^{\varpi_l} (l_{2,t})^{1-\varpi_l}, \quad (17)$$

6 In our model, borrowers can be thought of as renters who pay rent in the form of interest payments. The Korean housing market has a unique feature: the *Chonsei* system. In this system, homeowners can earn interest income from the deposits paid by their tenants or can use the deposits for other investments. *Chonsei* is similar to a long-term mortgage, but it can also be viewed as a short-term loan that continuously rolls over. In this process, the loan limit varies depending on the *Chonsei* price. If the price increases, the homeowner receives a larger loan amount, and if the price decreases, the homeowner must repay a portion of the principal according to the magnitude of the decline. Although some of *Chonsei* renters' assets are indirectly tied to housing, we consider such renters as borrowers, as they need to borrow funds to buy houses.

where $\Xi_l = (\varpi_l^{\varpi_l} (1 - \varpi_l)^{1-\varpi_l})^{-1}$ is a normalizing factor, ϖ_l is the weight of saver household labor, and l_t is the composite labor. The demands for labor from saver and borrower households are as follows:

$$l_{1,t} = \varpi_l \left(\frac{W_{1,t}}{W_t} \right)^{-1} l_t, \quad (18)$$

$$l_{2,t} = (1 - \varpi_l) \left(\frac{W_{2,t}}{W_t} \right)^{-1} l_t, \quad (19)$$

where $W_t = (W_{1,t})^{\varpi_l} (W_{2,t})^{1-\varpi_l}$ is the wage for composite labor l_t .

2.3 Non-housing production sector

The non-housing production sector produces consumer and investment goods and is owned by saver households. We denote the non-housing production sector with the subscript s . This sector's production function is given by

$$y_{s,t} = e^{\zeta_{a,t}} l_{s,t}^{\alpha_{s,l}} \bar{k}_{s,t}^{1-\alpha_{s,l}}, \quad (20)$$

where $\zeta_{a,t}$ is a productivity shock, $l_{s,t}$ is the labor input, $\bar{k}_{s,t}$ is the capital input, and $\alpha_{s,l}$ is the share of labor in the production function. The law of motion of capital stock is

$$\bar{k}_{s,t} = (1 - \delta_{s,k}) \bar{k}_{s,t-1} + e^{\zeta_{i,t}} i_{s,t} - \Omega_{s,t}^k (i_{s,t}, k_{s,t-1}), \quad (21)$$

where $\Omega_{s,t}^k (i_{s,t}, k_{s,t-1}) \equiv (\omega_{s,k}/2)((i_{s,t}/i_{s,t-1}) - \delta_{s,k})^2 k_{s,t-1}$ is the capital adjustment cost; $\zeta_{i,t}$ is an investment efficiency shock; and $i_{s,t}$ denotes non-residential investment.

Producers in the non-housing production sector minimize the following costs subject to the constraints given by equations (20) and (21).

$$E_t \left[\sum_{\tau=0}^{\infty} \beta_1^{\tau} \lambda_{1,t+\tau}^b \left(\frac{W_{t+\tau}}{P_{s,t+\tau}} l_{s,t+\tau} + i_{s,t+\tau} + \bar{k}_{s,t+\tau-1} \right) \right], \quad (22)$$

with the first-order conditions:

$$\lambda_{s,t}^p \alpha_{s,l} \frac{y_{s,t}}{l_{s,t}} - \beta_1 E_t [\lambda_{s,t+1}^p] = \lambda_{1,t}^b \frac{W_t}{P_{s,t}}, \quad (23)$$

$$\lambda_{s,t}^k e^{\zeta_{i,t}} \left[1 - \frac{\partial \Omega_{s,t}^i}{\partial i_{s,t}} \right] - \beta_1 E_t \left[\lambda_{s,t+1}^k e^{\zeta_{i,t+1}} \frac{\partial \Omega_{s,t+1}^i}{\partial i_{s,t}} \right] = \lambda_{1,t}^b, \quad (24)$$

$$\lambda_{s,t}^k = \beta_1 E_t \left[\lambda_{s,t+1}^k (1 - \delta_{s,k}) + \lambda_{s,t+1}^p (1 - \alpha_{s,l}) \frac{y_{s,t+1}^p}{\bar{k}_{s,t}} \right], \quad (25)$$

where $\lambda_{s,t}^p$ is the Lagrangian multiplier related to the production function and $\lambda_{s,t}^k$ is the Lagrangian multiplier associated with the law of motion of capital.

The nominal price also has rigidity, reflected by Calvo-type price adjustments. Specifically, the price is

adjusted with probability $1 - \theta_s$ and stays unchanged with probability θ_s . The log-linearized Keynesian Phillips curve can be obtained as

$$\pi_{s,t} = \beta_1 E_t[\pi_{s,t+1}] + \frac{(1 - \theta_s)(1 - \beta_1 \theta_s)}{\theta_s} \hat{\xi}_{s,t}, \quad (26)$$

where $\xi_{s,t} = \lambda_{s,t}^p / \lambda_{s,t}^b$ is the real marginal cost. The profit of the non-housing production sector, which is transferred to saver households, is given by

$$\frac{T_{s,t}}{P_{s,t}} = y_{s,t} - \frac{W_t}{P_{s,t}} l_{s,t} - i_{s,t}. \quad (27)$$

2.4 Housing production sector

The housing production sector builds new houses and sells them to households. This sector is labeled with the subscript h , and the houses are owned by savers. The housing production function is

$$y_{h,t} = e^{\zeta_{a_h,t}} l_{h,t}^{\alpha_{h,l}} k_{h,t-1}^{\alpha_{h,k}} m_{h,t}^{\alpha_{h,m}} n_{h,t}^{\alpha_{h,n}}, \quad (28)$$

where $y_{h,t}$ is a new house, $m_{h,t}$ denotes intermediate inputs from the non-housing production sector, $n_{h,t}$ denotes land inputs, and $\zeta_{a_h,t}$ is the technology shock in the housing production sector.

The law of motion for the accumulation of capital stock in the housing production sector is

$$k_{h,t} = (1 - \delta_{h,k}) k_{h,t-1} + e^{\zeta_{i_h,t}} i_{h,t} - \Omega_{h,t}^k (i_{h,t}, k_{h,t-1}), \quad (29)$$

where $\Omega_{h,t}^k (i_{h,t}, k_{h,t-1})$ takes a similar functional form to that of $\Omega_{s,t}^k (i_{s,t}, k_{s,t-1})$. As new houses are pre-sold before construction is completed in Korea, the price of a new house, $P_{h,t}^w$, is determined by the expected value γ periods ahead (i.e., at time $t - \gamma$), such that

$$P_{h,t}^w = E_{t-\gamma} [P_{h,t}]. \quad (30)$$

Because the price of a new house is determined in advance, the housing price is different from the price of a new house, i.e., $P_{h,t}^w \neq P_{h,t}$ in general. Thus, households who buy new houses may enjoy profits or losses depending on the price difference. The gains from this price difference, which are transferred from the housing production sector to savers, take the following form:

$$\frac{T_{h,2,t}}{P_{s,t}} = \left(\frac{P_{h,t}^w}{P_{s,t}} - \frac{P_{h,t}}{P_{s,t}} \right) (h_{2,t} - (1 - \delta_h) h_{2,t-1}) = -\frac{T_{h,1,t}}{P_{s,t}}, \quad (31)$$

where $T_{h,1,t}$ and $T_{h,2,t}$ are transfers to saving and borrowing households, respectively. The last equality comes from the assumption that the housing sector is owned by saver households.

2.5 Market-clearing conditions, MP, and shocks

The labor market-clearing condition is

$$l_{h,t} + l_{s,t} = l_t. \quad (32)$$

The total amount of land is normalized to equal one, and the market liquidation condition for the exogenously given land supply is

$$n_{h,t} = n_{1,t} = 1. \quad (33)$$

The market-clearing condition in the non-housing production sector is

$$c_{1,t} + c_{2,t} + i_{s,t} + i_{h,t} + m_{h,t} = y_{s,t}. \quad (34)$$

The condition for the liquidation of new houses is

$$(h_{1,t} - (1 - \delta_h) h_{1,t-1}) + (h_{2,t} - (1 - \delta_h) h_{2,t-1}) = y_{h,t}. \quad (35)$$

The bond market-clearing condition takes the following form:

$$B_{1,t} + B_{2,t} = 0. \quad (36)$$

Real GDP is defined as

$$y_t = y_{s,t} + \frac{P_{h,t}}{P_{s,t}} y_{h,t} - m_{h,t}. \quad (37)$$

Interest rates are set according to the standard Taylor rule:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) (\rho_\pi \hat{\pi}_{s,t} + \rho_y \hat{y}_t) + \varepsilon_{R,t}, \quad (38)$$

where $\varepsilon_{R,t} \sim N(0, \sigma_R)$ is the MP shock.

Finally, we assume that consumer preference ($\zeta_{c,t}$), housing demand ($\zeta_{h,t}$), non-housing production sector productivity ($\zeta_{a,t}$), investment efficiency ($\zeta_{i,t}$), and housing production ($\zeta_{a_h,t}$) shocks follow the autoregressive (AR) (1) processes

$$\zeta_{\kappa,t} = \rho_\kappa \zeta_{\kappa,t-1} + \varepsilon_{\kappa,t}, \quad (39)$$

where $\varepsilon_{\kappa,t} \sim N(0, \sigma_\kappa^2)$ and $\kappa \in \{c, h, a, i, a_h\}$.

3 Calibration and estimation

3.1 Calibration

We provide numerical values for some parameters that are calibrated to ensure that the proposed model is in line with Korean data or established literature on the Korean economy. First, we set the time discount rate (β_1) for saver

households as 0.99, which implies that the steady-state value of the annual interest rate is 4%, and we set the time discount rate (β_2) for borrower households as 0.97. The discount rate for borrower households is lower than that for saver households to ensure that these households have sufficient motives for borrowing and that the borrowing constraints are binding in the steady state, following Lee and Song (2015). The LTV ratio for borrower households, Φ_2 , is set equal to 0.7, reflecting the national average in Korea over the estimation period. We set $\alpha_{s,l}$ in the non-housing production sector equal to 0.6, reflecting the labor share of 0.62–0.64 calculated by the Bank of Korea, which is Korea's monetary authority. The parameters $\alpha_{h,k}$, $\alpha_{h,m}$, and $\alpha_{h,n}$ in the housing production sector are set to 0.1, 0.1, and 0.2, respectively, to allow the share of labor in the housing production sector to be 0.6. As the existing literature does not provide much information on the share of land, we set it to be slightly higher than the value found in Davis and Heathcote (2005) to match the observation that the returns from land investments are approximately twice than those of equity investments in Korea.

The non-housing sector markup parameters, ϕ_s and ϕ_l , are set to 1.15 under the assumption of a 15% markup in the steady state, as in Lee and Song (2015) and Noh (2020). We set $\delta_{s,k}$ and $\delta_{h,k}$, the depreciation rates of capital in the non-housing and housing production sectors, respectively, equal to 0.025 and 0.005. These values imply steady-state non-residential investment-to-GDP and residential investment-to-GDP ratios of 25.2% and 4.8%, respectively. The depreciation rate of the housing stock, δ_h , is set to 0.01 based on the Bank of Korea's finding that the annual depreciation rate of the housing stock is 0.048.⁷ The weight of housing (χ_h) in the utility function is set to 0.2 to imply that the housing stock is ten times greater than habit-adjusted consumption (i.e., $\frac{h_1}{(1-b)c} = 10$). The weight of leisure (χ_l) is set to 5.565, allowing leisure time to equal one-third of the time spent working in the steady state.

3.2 Data and estimation

The data used in the estimation are the real private consumption ($c_t (= c_{1,t} + c_{2,t})$), the non-residential investment ($i_{s,t}$), the residential investment ($i_{h,t}$), the inflation rate

($\pi_{s,t}$), the real housing price ($\frac{P_{h,t}}{P_{s,t}}$), and the call rate (R_t). The estimation period is from the first quarter of 2000 to the second quarter of 2017. In the estimation, all data, except for the inflation and call rates, are log-transformed, and the data are then detrended using a Hodrick–Prescott filter. The observed data are plotted in Figure 3.

The model parameters are estimated using the Bayesian method, and the priors and the posteriors are presented in Table 1. The prior distributions for the parameters are determined by referring to Iacoviello and Neri (2010) and Lee and Song (2015). Following the convention in much of the literature, the prior distributions are set as loosely as possible to achieve reasonably good statistical properties for the whole estimation. We set the prior mean of ρ_π , which represents the central bank's response to inflation, equal to 3 to match inflation rate volatility, as Iacoviello and Neri (2010) set it to 1.5. The prior means for the capital adjustment cost parameters, $\omega_{s,k}$ and $\omega_{h,k}$, are set to 45 to match the average volatilities of both non-housing and housing investment over the estimation period.

To check the model's fit to the data, we compare the simulated moments from the model with those in the data and present the results in Table 2. The volatilities and correlations of most of the observable data are fairly well-matched with the model except for non-housing investments and the non-housing sector inflation rate.

Figure 4 decomposes the historical housing production and real housing price data by the types of shocks identified over the sample period. We find that the soaring housing prices between 2006 and 2008 were mainly caused by the growing demand for houses. This excess demand for houses has faded since 2009. The sudden fall in technology shocks in residential construction explains the slowdown in housing production after 2011. The upswing in housing production since 2015 can be explained by the rebound in these technology shocks as well as the recovered demand for houses.

3.3 Empirical analysis

This subsection provides the response functions of the endogenous variables to each shock and checks whether the model's predictions are consistent with the stylized facts given by theory and data. Figure 5 shows the responses of real GDP (y), non-housing inflation (π_s), nominal interest rate (R), consumption (c), housing production (y_h), and the real housing price ($\frac{P_{h,t}}{P_{s,t}}$) to

⁷ Depreciation rates by the type of physical asset are estimated by the Bank of Korea and can be found at <http://www.bok.or.kr/portal/bbs/B0000233/view.do?nttId=155482&menuNo=200707>

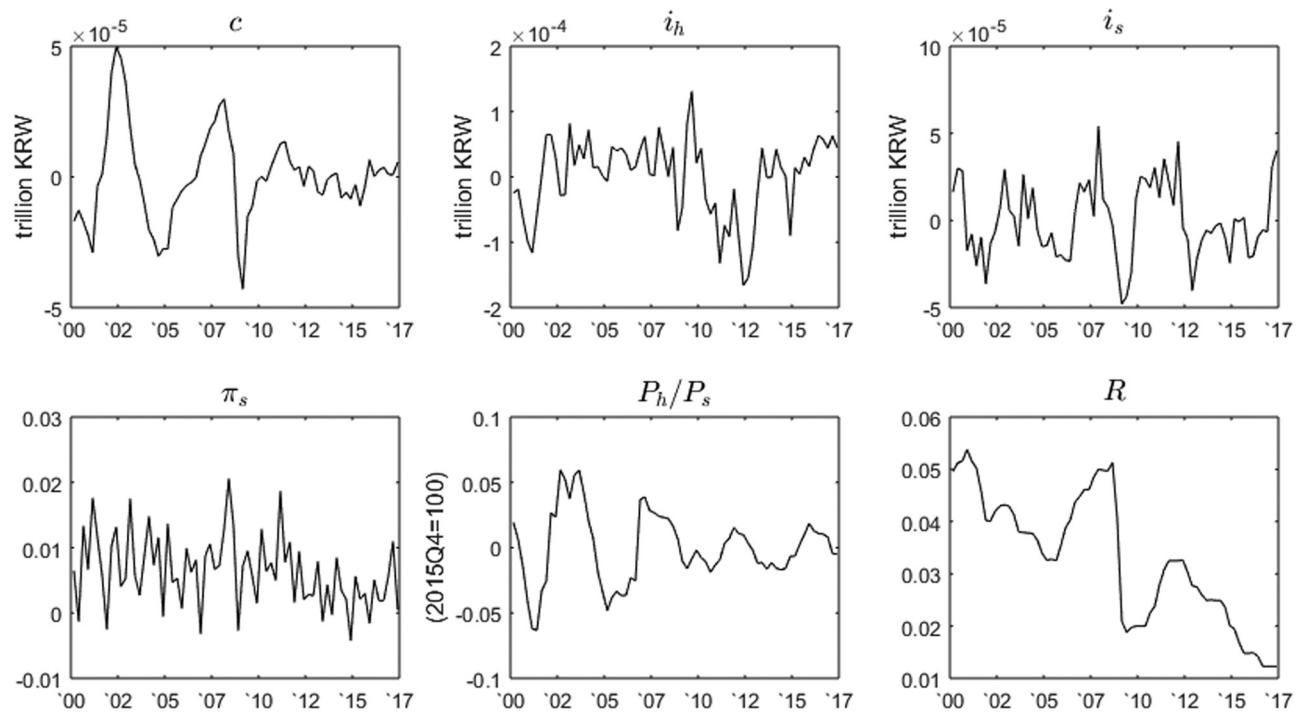


Figure 3: Hodrick–Prescott filtered sample data.

Table 1: Priors and posteriors

Parameters	Priors			Posteriors				
	Type	Mean	Std.	5%	Mean	Mode	95%	
Habit formation	b	Beta	0.5	0.1	0.396	0.488	0.489	0.578
Standard sector price stickiness	θ_s	Beta	0.667	0.1	0.486	0.572	0.557	0.643
Wage stickiness	θ_w	Beta	0.667	0.1	0.580	0.657	0.654	0.733
Standard household labor weight	ω_l	Beta	0.65	0.05	0.555	0.633	0.635	0.711
AR aggregate tech shock	ρ_a	Beta	0.6	0.1	0.519	0.646	0.675	0.773
AR construction sector tech shock	ρ_{ah}	Beta	0.6	0.1	0.506	0.620	0.627	0.732
AR investment efficiency shock	ρ_i	Beta	0.6	0.1	0.456	0.555	0.559	0.656
AR consumer preference shock	ρ_c	Beta	0.6	0.1	0.451	0.551	0.557	0.651
AR housing demand shock	ρ_h	Beta	0.6	0.1	0.700	0.761	0.766	0.824
MP interest rate smoothing	ρ_R	Beta	0.6	0.1	0.679	0.732	0.734	0.787
Standard sector capital adjust.	$\omega_{s,k}$	Inv. G	45	2	35.209	48.781	45.421	62.440
Housing sector capital adjust.	$\omega_{h,k}$	Inv. G	45	2	28.747	45.059	43.148	60.935
Aggregate tech shock std.	σ_a	Inv. G	0.001	0.05	0.0078	0.0116	0.0104	0.0150
Housing sector tech shock std.	σ_{ah}	Inv. G	0.001	0.05	0.0132	0.0155	0.0151	0.0176
Investment efficiency shock std.	σ_i	Inv. G	0.001	0.05	0.019	0.026	0.024	0.033
Consumer preference shock std.	σ_c	Inv. G	0.001	0.05	0.016	0.020	0.020	0.025
Housing demand shock std.	σ_h	Inv. G	0.001	0.05	0.150	0.215	0.203	0.277
MP shock std.	σ_R	Inv. G	0.001	0.05	0.004	0.005	0.005	0.006
MP inflation response	ρ_π	Normal	3	0.1	2.829	2.974	2.971	3.156
MP output gap response	ρ_y	Normal	0	0.1	0.470	0.665	0.640	0.833

Note: The posteriors are estimated using the Bayesian method with 110,000 simulations. The first 10,000 simulations are considered a burn-in period and are discarded.

Abbreviations: AR – autoregressive; MP – monetary policy.

Table 2: Comparison of moments

	c	i_s	i_h	π_s	P_h/P_s	R
SD (%)						
Data	1.75	2.19	6.09	0.50	2.71	0.60
Model	1.48	2.18	5.80	0.53	2.30	0.48
Cross-correlation with i_h						
Data	0.16	-0.04	1.00	-0.01	0.19	-0.21
Model	0.37	0.25	0.91	-0.22	1.00	-0.48
Autocorrelation (order = 1)						
Data	0.84	0.57	0.64	-0.15	0.84	0.86
Model	0.72	0.47	0.51	0.24	0.59	0.56

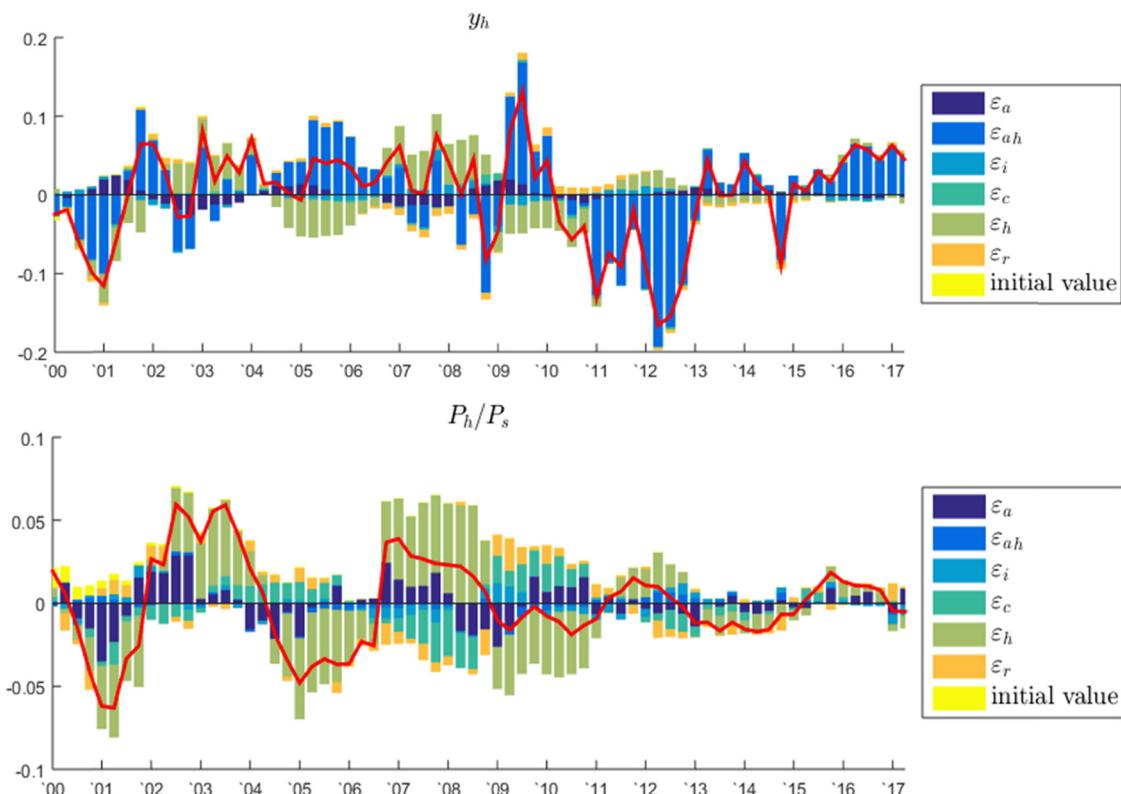
Note: Model moments are calculated using 10,000 simulations of the same length as the data. These simulations are generated by resampling the shocks identified over the sample period using the posterior means of the model parameters.

productivity shocks in non-housing production ($\varepsilon_{a,t}$). Because higher productivity reduces the marginal cost of production, each firm lowers the price of its goods to maximize profits. As a result, prices fall, consumption and investment increase, and output increases, which is consistent with the predictions of standard macroeconomic theory.

Figure 6 shows the responses to a productivity shock ($\varepsilon_{a_h,t}$) in the housing production sector. Residential construction investment and housing production both increase as a result. Real GDP also increases, and real housing prices fall. As economic resources move from non-housing to housing production, consumption decreases, and general inflation increases. In response to this rising inflation, nominal interest rates rise as well.

Figure 7 shows the responses to a consumption preference shock ($\varepsilon_{c,t}$). Consumption increases as the preference for consumption increases, leading to increases in both real GDP and prices. In response, the monetary authority raises the nominal interest rate. In the housing production sector, housing investment falls as resources shift to consumer goods, causing housing production to decrease. Real housing prices fall as nominal housing prices rise and non-housing prices rise even more.

Figure 8 shows the responses to a negative housing preference shock ($\varepsilon_{h,t}$). If housing preferences experience a negative shock, housing investment declines, and the real housing prices fall. Reduced residential investment also lowers real GDP. As housing prices decline, borrower households' consumption declines, owing to the tightening of collateral constraints. As a result, overall

**Figure 4:** Historical decompositions.

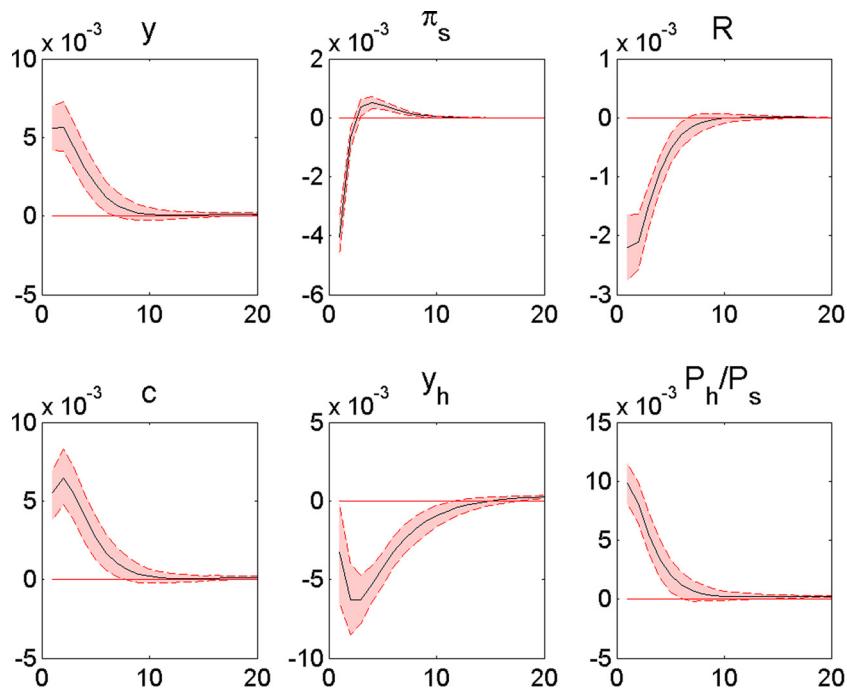


Figure 5: Responses to a productivity shock in the non-housing production sector ($\varepsilon_{a,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a productivity shock in the non-housing production sector.

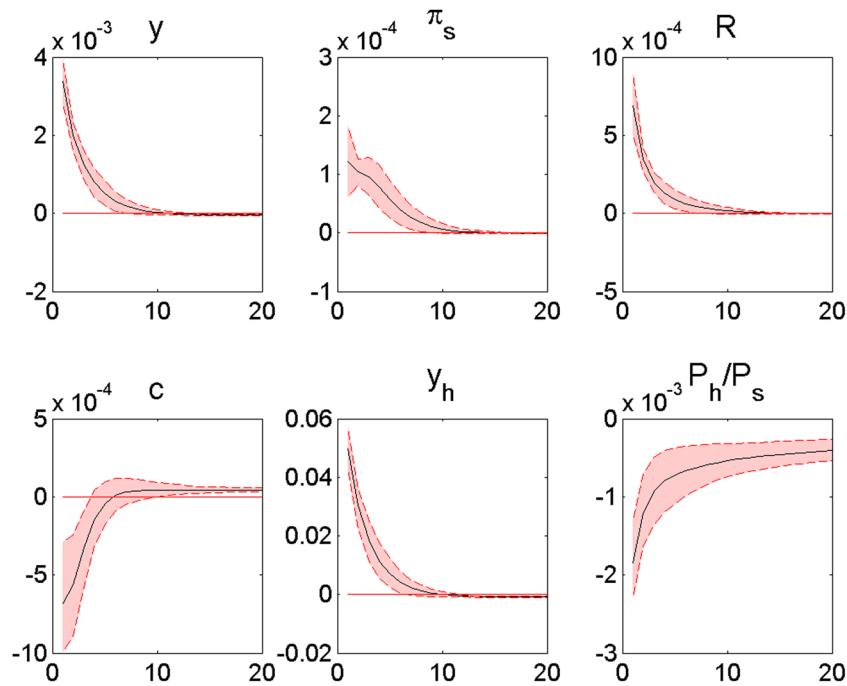


Figure 6: Responses to a productivity shock in the housing production sector ($\varepsilon_{a_h,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a productivity shock in the housing production sector.

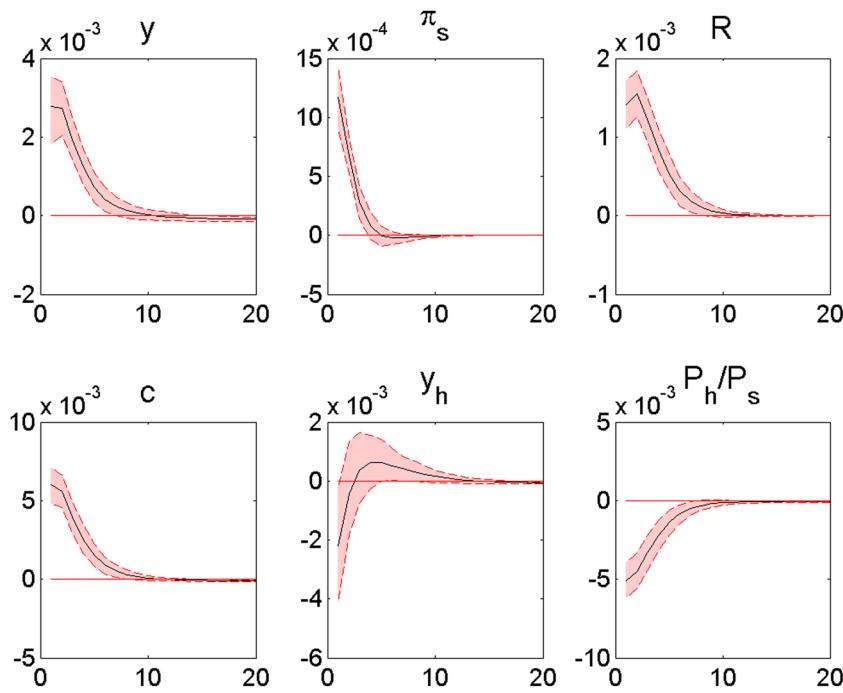


Figure 7: Responses to a consumption preference shock ($\varepsilon_{c,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a consumption shock.

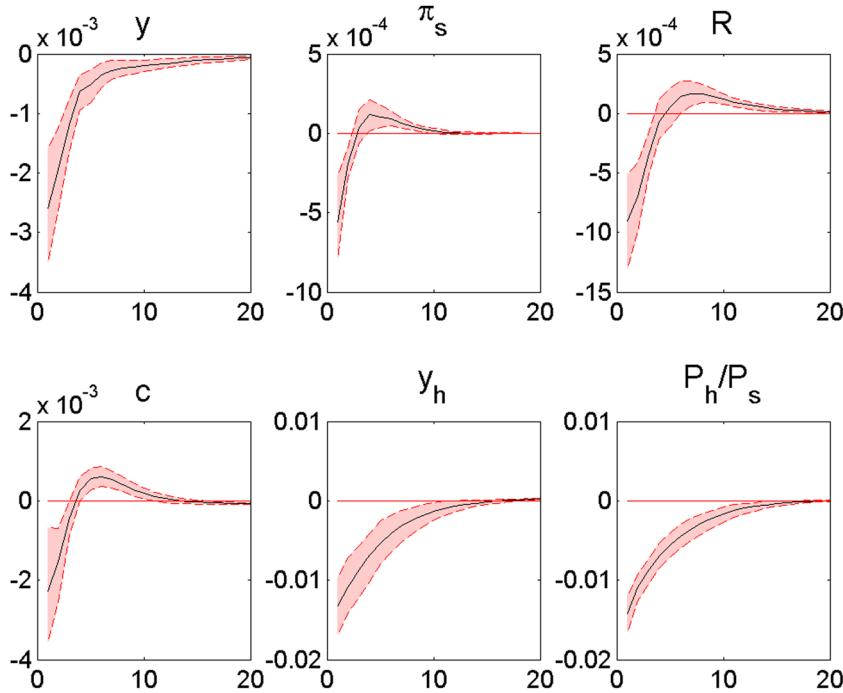


Figure 8: Responses to a negative housing preference shock ($\varepsilon_{h,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a negative housing preference shock.

consumption and general inflation decline, and nominal interest rates decline in response to falling general inflation.

Figure 9 shows the responses to an investment efficiency shock ($\varepsilon_{i,t}$). As investment efficiency increases, the price of intermediate inputs from the non-housing sector

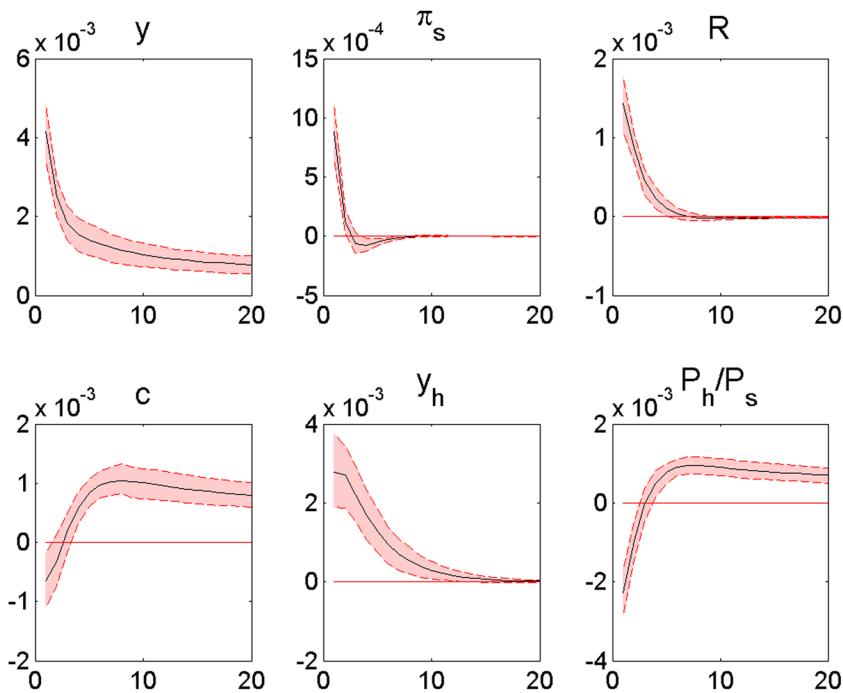


Figure 9: Responses to an investment efficiency shock ($\varepsilon_{I,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following an investment efficiency shock.

decreases, housing investment increases, and, hence, real GDP increases. As the returns from the housing sector become higher than those from the non-housing sector, resources are transferred to the housing sector, and consumption and real housing prices fall owing to

the increased housing supply. The resulting higher income causes consumption to increase over time.

Figure 10 shows the responses to an exogenous MP shock ($\varepsilon_{R,t}$). If the nominal interest rate rises owing to this shock, real GDP, consumption, and housing investment

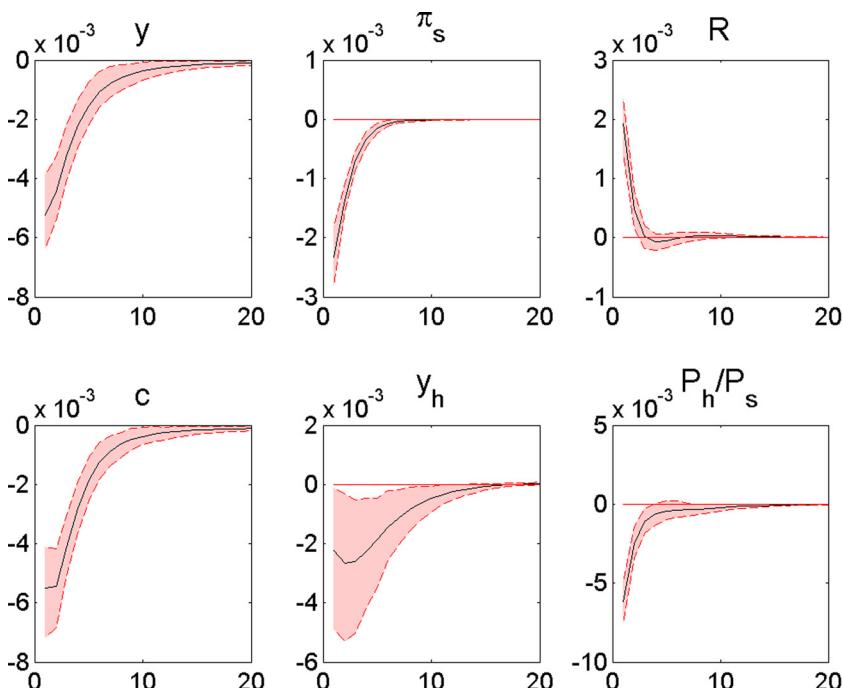


Figure 10: Responses to an MP shock ($\varepsilon_{R,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following an MP shock.

decline, and the real housing price also declines, indicating that the housing price is more sensitive to a monetary shock than the non-housing price. This finding implies that asset prices respond faster to a monetary shock than general consumer prices do.

Table 3 shows the forecasting error variance decomposition results for key macroeconomic variables. The table shows that consumption (c_t), investment (i_t), general price inflation rate ($\pi_{s,t}$), and nominal interest rate (R_t) are mostly explained by non-housing-related structural shocks and monetary shocks. In the housing production sector, housing preference shocks have lower explanatory power than housing productivity shocks, implying that housing market fluctuations are explained more by changes on the supply side than by those on the demand side. This finding reflects the housing shortage in Korea. However, the explanatory power of demand-side factors increases over time. Demand has more forecasting

power for real housing prices than the supply-side factors. This result suggests that demand fluctuations reflect most of the movements in housing prices, as it is difficult to increase the housing supply in the short term.

4 Comparative static analyses

4.1 Lowering the LTV ceiling

To examine the macroeconomic effects of household debt deleveraging, we reduce the LTV ceiling from the baseline fixed at 70% in the estimation to 50%. As the LTV ratio declines, borrowers face relatively high pressure to deleverage. In the case of housing preferences and MP shocks, the impact of the LTV ratio is more pronounced.

Table 3: Forecasting error variance decomposition of structural shocks

Quarter	y			π_s			R		
	1	4	20	1	4	20	1	4	20
ε_a	0.320	0.408	0.386	0.694	0.631	0.634	0.368	0.460	0.458
ε_{ah}	0.115	0.076	0.069	0.001	0.001	0.002	0.034	0.023	0.023
ε_c	0.081	0.091	0.085	0.057	0.068	0.067	0.146	0.233	0.239
ε_h	0.060	0.049	0.047	0.011	0.012	0.012	0.051	0.045	0.049
ε_i	0.169	0.123	0.169	0.031	0.028	0.027	0.140	0.103	0.100
ε_R	0.255	0.252	0.244	0.206	0.261	0.258	0.260	0.136	0.132
Quarter	c			y_h			P_h/P_s		
	1	4	20	1	4	20	1	4	20
ε_a	0.313	0.410	0.400	0.005	0.032	0.041	0.273	0.277	0.251
ε_{ah}	0.004	0.003	0.002	0.924	0.865	0.845	0.009	0.008	0.011
ε_c	0.366	0.300	0.278	0.001	0.001	0.001	0.071	0.081	0.074
ε_h	0.042	0.022	0.023	0.064	0.091	0.101	0.535	0.569	0.592
ε_i	0.004	0.003	0.041	0.003	0.005	0.006	0.014	0.008	0.019
ε_R	0.270	0.263	0.255	0.002	0.005	0.007	0.099	0.058	0.052
Quarter	i			y_s			P_h^w/P_s		
	1	4	20	1	4	20	1	4	20
ε_a	0.146	0.195	0.188	0.408	0.510	0.484	0.101	0.065	0.058
ε_{ah}	0.002	0.002	0.001	0.000	0.000	0.000	0.012	0.018	0.042
ε_c	0.037	0.054	0.054	0.103	0.100	0.092	0.045	0.031	0.025
ε_h	0.002	0.002	0.007	0.031	0.021	0.019	0.821	0.842	0.753
ε_i	0.761	0.709	0.712	0.179	0.118	0.165	0.017	0.039	0.117
ε_R	0.053	0.039	0.038	0.280	0.250	0.239	0.004	0.005	0.006

Note: The variance decomposition indicates the amount of information that each structural shock contributes to the endogenous macroeconomic variables. This decomposition shows how much of the forecasting error variance of each macroeconomic variable can be explained by each of the five structural shocks. The forecasting error variances of the endogenous variables explained by each structural shock in a given period sum to one.

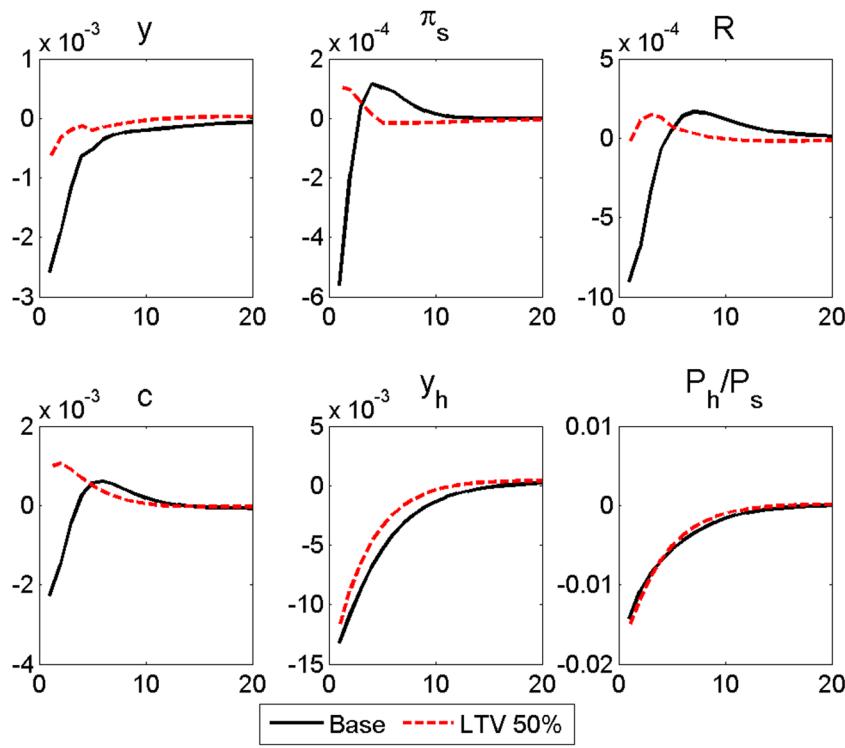


Figure 11: Responses to a negative housing preference shock ($\varepsilon_{h,t}$) by LTV ratio. Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a negative housing preference shock depending on the LTV ratio.

Figure 11 shows that a negative housing preference shock decreases the relative price of housing in the short term when the LTV ceiling is reduced below the baseline. However, the relative price of housing is higher than the baseline prediction as time passes. In contrast, the macroeconomic indicators, such as consumption and non-housing and housing production, contract less when the LTV ceiling is reduced relative to the baseline following a negative housing preference shock. As households already borrow less under a 50% LTV ceiling and the marginal utility from housing services is even higher relative to the baseline, a negative housing preference shock is less likely to change the marginal rate of substitution between housing and non-housing consumption. Non-housing consumption increases following a negative housing preference shock, meaning that prices and, thus, nominal interest rates rise according to the MP rule as well. As a result, a downward adjustment of the LTV ratio significantly insulates the real economy from the impact of a negative housing preference shock relative to the baseline outcomes.

When the LTV ceiling is adjusted downward, the effects of exogenous monetary shocks on real GDP, inflation, consumption, and housing production are also relatively moderate compared to the baseline estimates, as shown in Figure 12. However, the relative housing price declines more

than in the baseline case because housing prices respond more elastically to the interest rate than the general prices. As in the case of a negative housing preference shock, the downward adjustment of the LTV ceiling attenuates the impacts of an exogenous monetary shock and limits the effects of economic fluctuations.

4.2 Housing-price-augmented MP rule

We now modify Taylor's rule to reflect housing prices as follows:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R)(\rho_\pi \hat{\pi}_{s,t} + \rho_y \hat{y}_t + \rho_{hh} \hat{h}_t) + \varepsilon_{R,t}. \quad (40)$$

Here, ρ_{hh} , the MP response coefficient for the housing price (HP), is set equal to ρ_π . We examine the economy's response to this new MP rule (the HP Taylor rule, hereafter). Figure 13 shows the impacts of a negative housing preference shock. The responses of housing production and the relative housing and non-housing prices do not change much relative to the baseline case. However, the real variables follow different paths in response to a negative housing preference shock when the MP rule is changed. When housing prices decline owing to a negative housing preference shock, the nominal interest rate

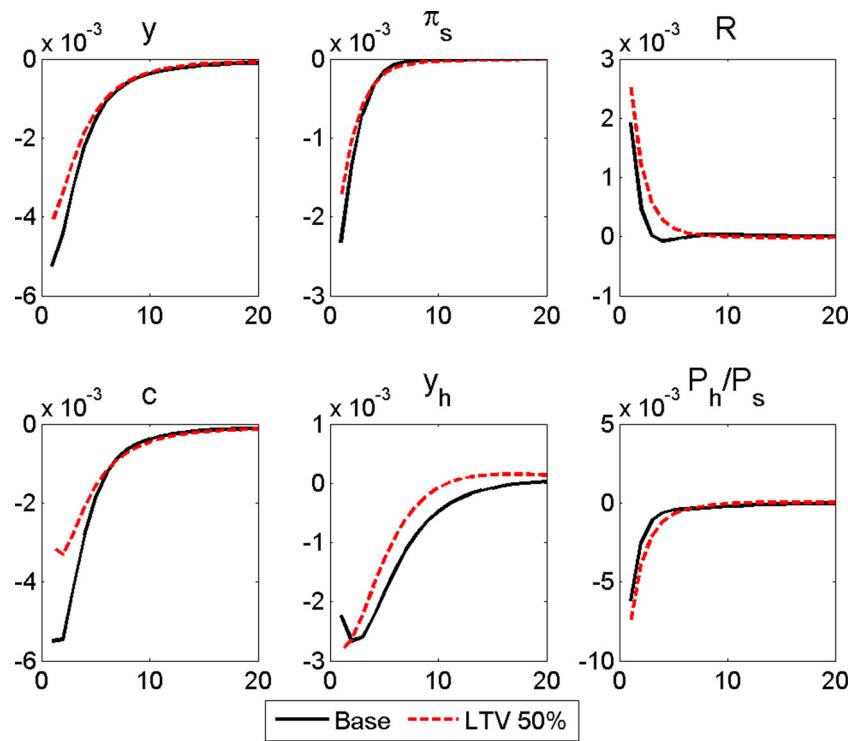


Figure 12: Responses to an MP shock ($\varepsilon_{R,t}$) by LTV ratio. Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following an MP shock depending on the LTV ratio.

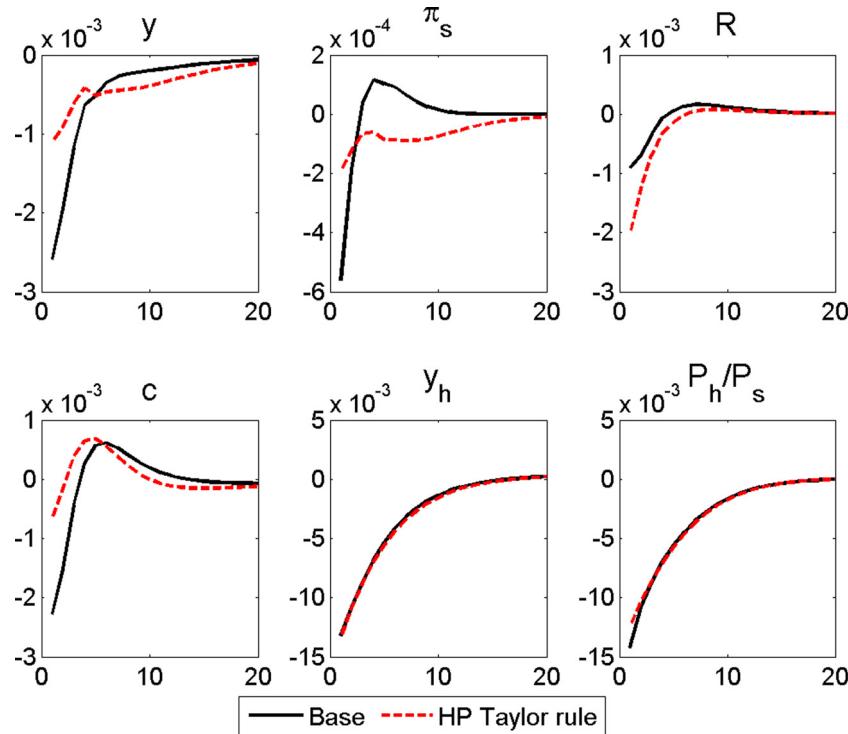


Figure 13: Responses to a negative housing preference shock ($\varepsilon_{h,t}$) according to the MP rule. Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a negative housing preference shock with and without housing price gaps in the MP rule.

declines and, thus, production and consumption increase relative to the baseline case, resulting in higher inflation than in the baseline case as well.

In the case of an exogenous MP shock, a higher interest rate lowers real GDP, consumption, residential construction investment, and housing and non-housing prices, as presented in Figure 14. A rise in nominal interest rates causes non-housing prices to decline as a result of reduced consumption and housing prices as borrowers face tighter collateral constraints and lower demand for houses. The nominal interest rate then decreases as the consumer price and asset prices fall over time. When we compare these results to the corresponding results in the baseline cases, the differences are very negligible. Thus, the monetary response to housing price inflation has limited macroeconomic implications in Korea.

4.3 Lowering the LTV ceiling and setting a house-price-augmented MP rule

Now, we consider the hypothetical situation in which the LTV ceiling is reduced to 50% and the central bank follows a new MP rule that takes housing prices into

account. In this case, the changes in real GDP, consumption, and inflation in response to a negative housing preference shock, considering the baseline, decrease only slightly or even increase, as presented in Figure 15. Owing to the downward adjustment of the LTV ratio, which regulates the maximum percent of the value of a purchased house that a household can borrow, the impact of a negative housing preference shock is limited. The decline in housing prices reinforces this mitigating effect by adjusting the nominal interest rate down to better absorb the shock relative to the baseline case.

Figure 16 shows the responses to an MP shock in the baseline case and the hypothetical scenario. Because an MP shock has little impact on economic fluctuations, most of the fluctuations must be attributed to the downward adjustment of the LTV ceiling. As the nominal interest rate rises, real GDP, consumption, and inflation decline. However, they fall more gradually in the hypothetical scenario than in the baseline case. This result can be attributed to the decrease in the burden of interest payments. As the stronger LTV restriction limits the amount that borrowers can afford to borrow at the margin, the change in borrowers' interest payments due to the rise in the interest rate is less severe than in the baseline. Housing prices, which are most sensitive to nominal

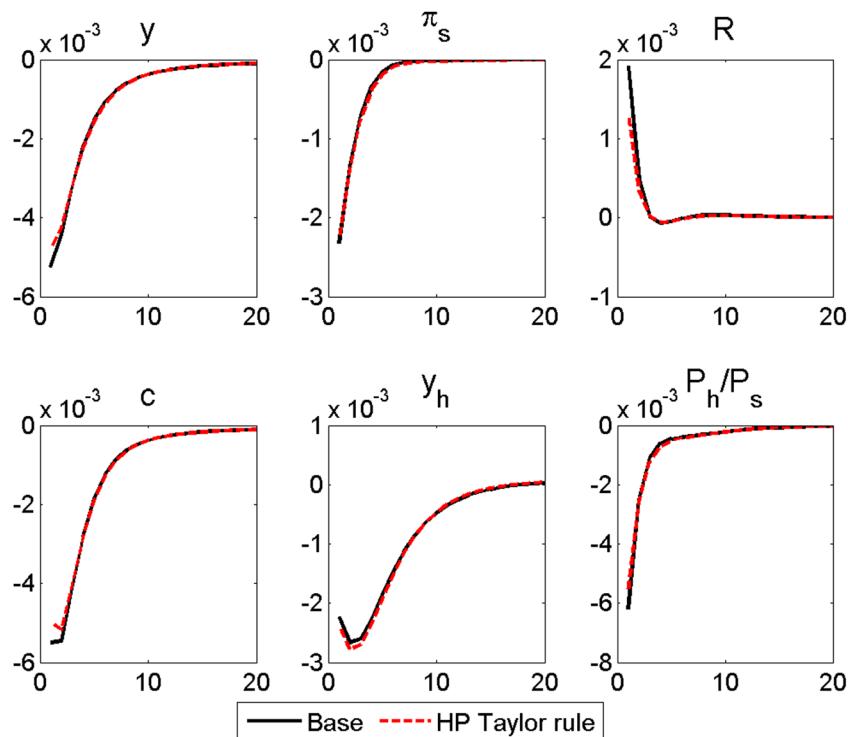


Figure 14: Responses to an MP shock ($\epsilon_{R,t}$) according to the MP rule. Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following an MP shock with and without housing price gaps in the MP rule.

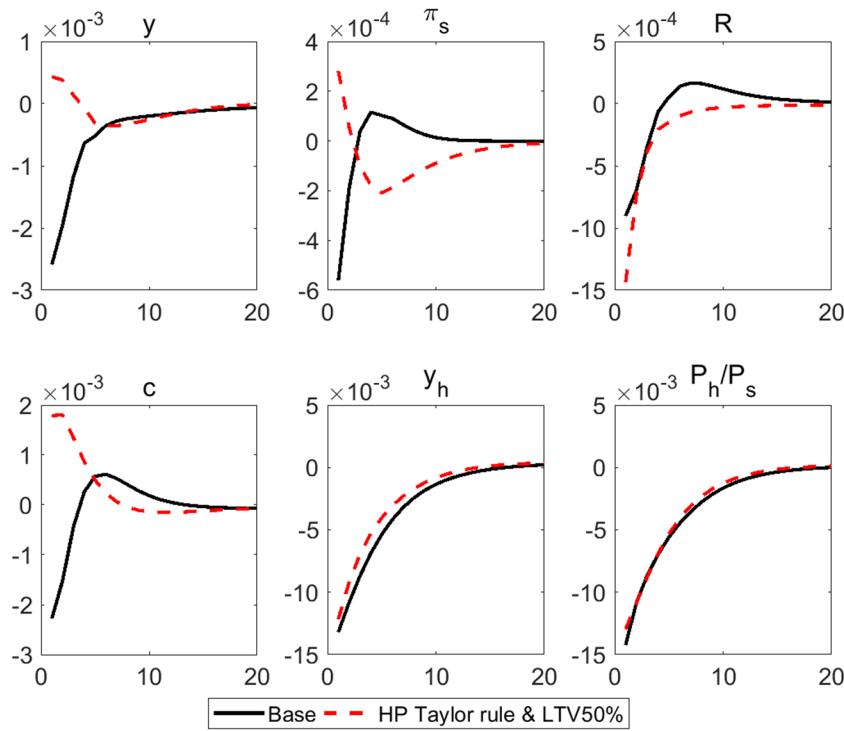


Figure 15: Response to a negative housing preference shock ($\epsilon_{h,t}$) according to the MP rule and LTV ratio. Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following a negative housing preference shock in both the baseline scenario and the hypothetical scenario with a 50% LTV ceiling and an MP rule that includes the housing price gap.

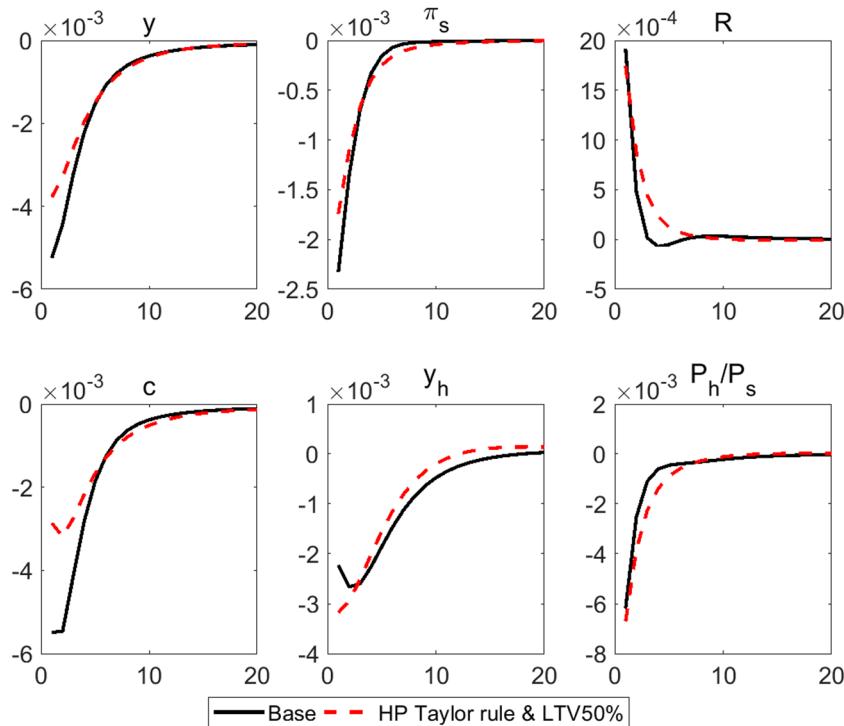


Figure 16: Response to an MP shock ($\epsilon_{R,t}$) according to the MP rule and the LTV ratio. Note: The x-axis shows the quarter, and the y-axis shows the deviation of the given endogenous variable from its equilibrium value following an MP shock in both the baseline scenario and a hypothetical scenario with a 50% LTV ceiling and an MP rule that includes the housing price gap.

interest rates, decline rapidly, and their decline, relative to non-housing prices, is greater than in the baseline case. The lower the LTV ceiling is, the harder it becomes to borrow funds using a house as collateral, and, hence, housing prices become more sensitive to changes in interest rates.

These results suggest that the economy can be further insulated from the impacts of a negative housing preference shock by introducing a tighter LTV ceiling and an MP rule that considers housing price inflation.

4.4 Welfare distribution after shocks

A welfare analysis can reveal the distinct responses of the borrowers and savers, separately, to a given shock (Menno & Oliviero, 2020). In this subsection, we decompose the welfare response to each shock by household type and observe the changes in this response when the LTV requirement tightens. Figure 17 presents the welfare responses under an LTV ratio of 70%. When the economy is hit by a consumption preference or housing sector productivity shock, the borrowers' welfare increases relative to that of the savers. As the borrowers' value of housing increases under these shocks, they accumulate more housing for current use and as collateral for future consumption, resulting in greater welfare for the borrowers.

Figure 18 presents the welfare responses when the LTV requirement is reduced to 50%. Under this tighter collateral requirement, the scale of the y -axis alone shows that the welfare variations are relatively subdued compared to the case with a looser collateral constraint. Interestingly, the welfare responses to the consumption preference and housing sector productivity shocks are reversed. In the previous case, these shocks lead to greater welfare for the borrowers than for the savers. With a lower LTV requirement, however, this result no longer occurs, although the differences are not large. One possible explanation for this reversal is that a tighter LTV requirement reduces the collateral value of housing and, thus, the borrowers' ability to substitute consumption intertemporally is limited. This explanation is only partial, and further analysis is required to fully understand this result. We leave this for future research. For now, we show that deleveraging through a tighter LTV requirement has a distributional welfare effect, which many other studies have overlooked (Cloyne, Ferreira, & Surico, 2020; Justiniano et al., 2015, 2019; Liu and Ou, 2021).

4.5 Sensitivity of the MP rule to housing price shocks

In the previous analysis, we set the value of ρ_{hh} , the MP response coefficient for a housing price shock, to be symmetric to ρ_π . Because the MP response to collateral constraints is sensitive to this coefficient, we conduct some robustness checks to observe changes in the aggregate utility of the economy as ρ_{hh} changes. The aggregate welfare (W) is defined as the sum of the current and discounted future expected utilities of the saver and borrower households.

To conduct robustness checks on the value of ρ_{hh} , we gradually increase ρ_{hh} from 0.0 to 1 by increments of 0.1. The changes in the aggregate utility when $\rho_{hh} = \{0, 0.2, 0.4, 0.6, 0.8, 1.0\}$ are shown in Figure 19. The baseline scenario is $\rho_{hh} = 0.0$. First, we observe that no single dominant ρ_{hh} value overrides all the others. A higher ρ_{hh} performs better in response to preference shocks, whereas a lower ρ_{hh} performs better in response to productivity shocks. It is unclear which values of ρ_{hh} perform better in response to MP shocks. As MP shocks affect housing prices indirectly through output gaps or inflationary pressure, housing prices play a rather limited role in the monetary reaction function and do not meaningfully affect the welfare of the overall economy.

In the case of other shocks, a policy rule that incorporates housing prices serves to increase aggregate welfare. In particular, this policy rule works fairly well when the economy is hit by a demand shock rather than a supply shock. In the case of a preference shock, regardless of whether it is housing-related, aggregate welfare increases when the central bank reacts procyclically in response to the shock. However, if the economy is hit by a supply shock, a proactive MP in response to a housing price hike leads to lower aggregate welfare than in the baseline case. These results reveal that MP should respond asymmetrically depending on the source of a shock to facilitate overall economic welfare. As Cloyne et al., (2020) point out, these results can be interpreted as the impact of an interest rate shock decreasing as the proportion of mortgage payments decreases.

5 Conclusion and policy implications

This study systematically discusses the effects of the MP in Korea during household debt deleveraging, which is

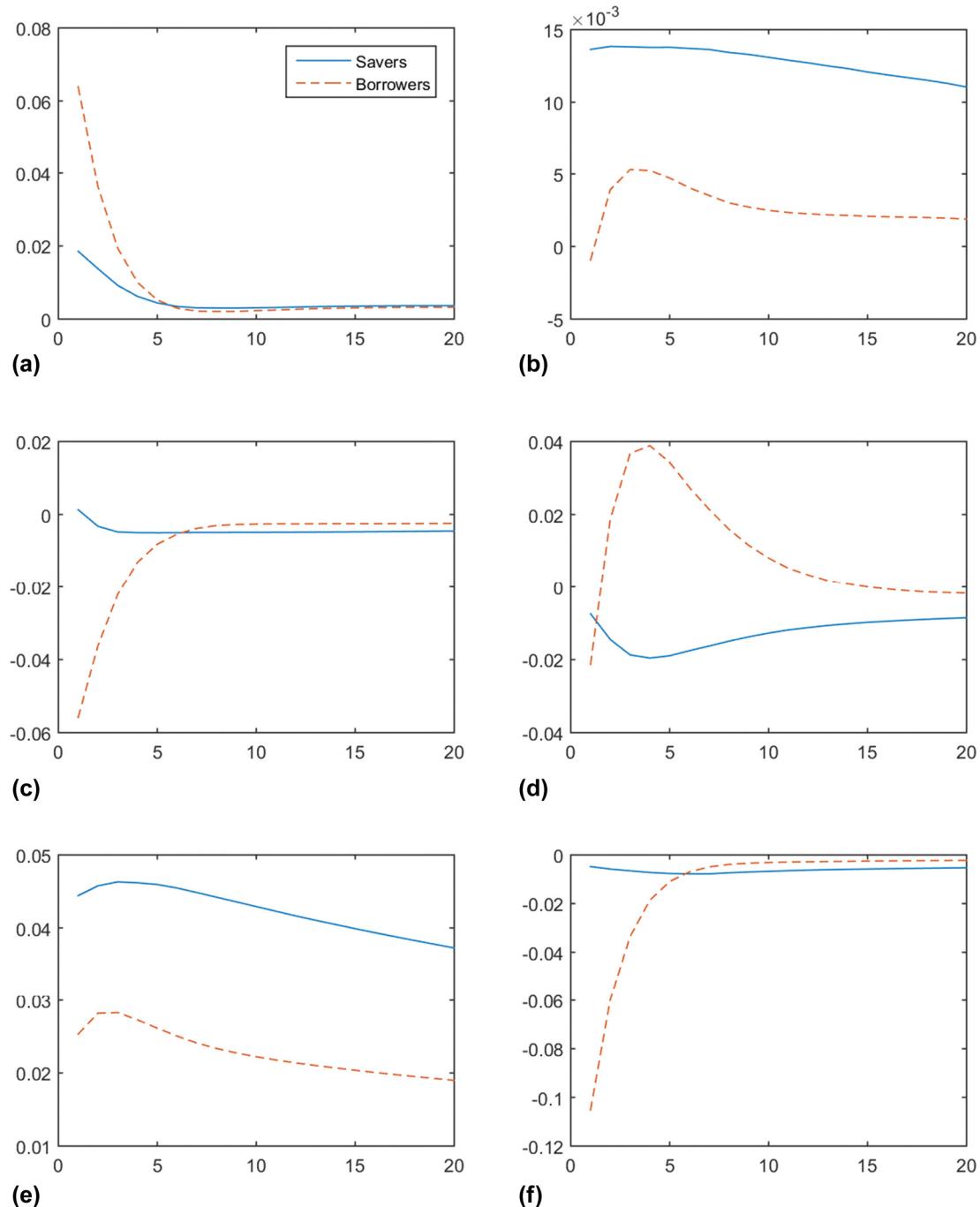


Figure 17: Welfare responses by type of shock with a 70% LTV ceiling: savers vs borrowers. (a) Consumption preference shock ($\varepsilon_{c,t}$). (b) Housing preference shock ($\varepsilon_{h,t}$). (c) Non-housing sector productivity shock ($\varepsilon_{a,t}$). (d) Housing sector productivity shock ($\varepsilon_{a_h,t}$). (e) Investment efficiency shock ($\varepsilon_{i,t}$). (f) MP shock ($\varepsilon_{R,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of aggregate welfare from its equilibrium value.

not widely studied in developing countries and emerging economies. Although the household debt associated with housing is an essential factor in MP operation, high interest rates and underdeveloped consumer financial markets make policymakers overlook its significance.

With the development of consumer financial markets and the expansion of housing demand since the early 2000s, Korea's household debt began to skyrocket and reached a doorstep to concern and manage its size and growth. This provides an essential motivation for this

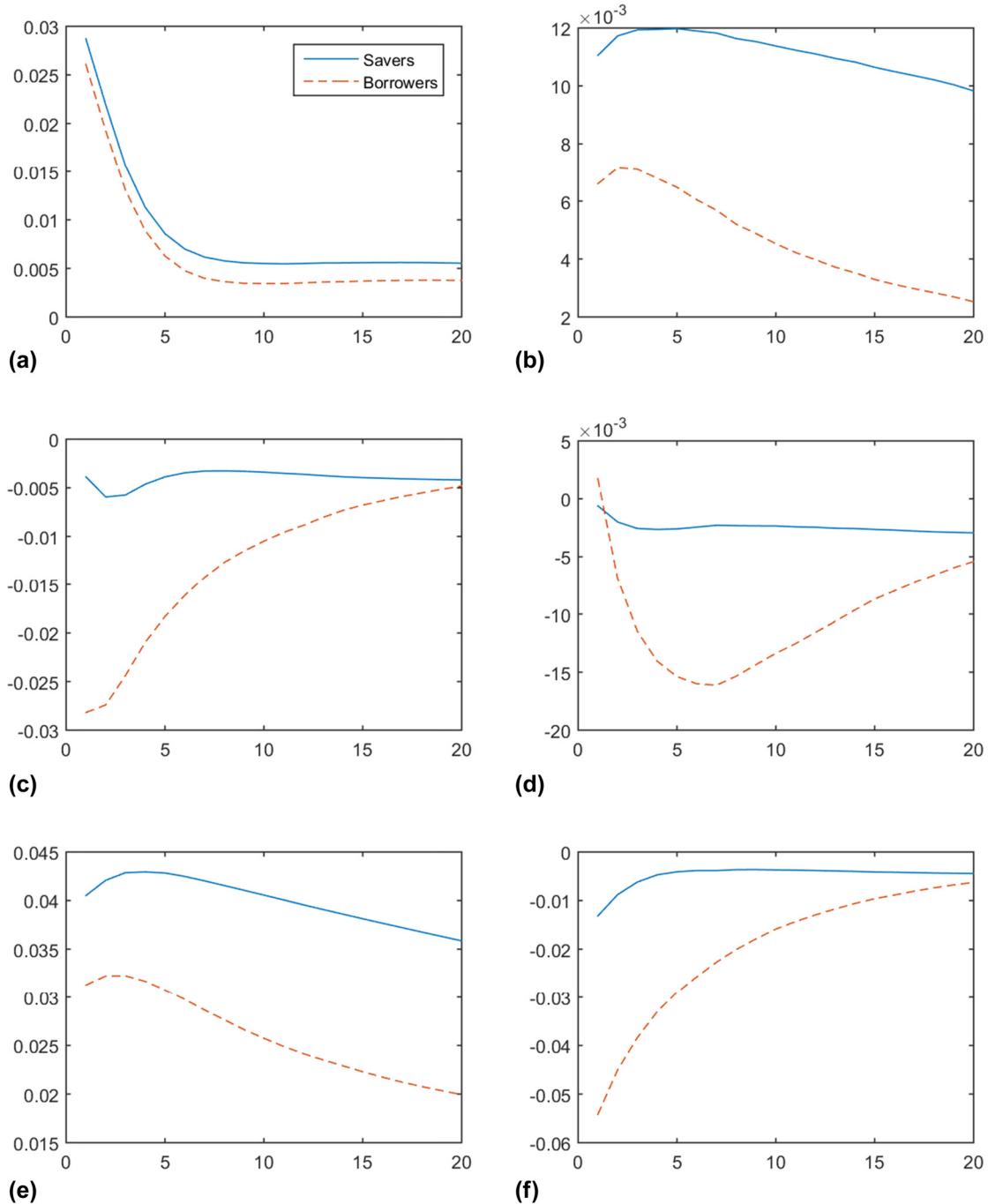


Figure 18: Welfare responses by type of shock with a 50% LTV ceiling: savers vs borrowers. (a) Consumption preference shock ($\varepsilon_{c,t}$). (b) Housing preference shock ($\varepsilon_{h,t}$). (c) Non-housing sector productivity shock ($\varepsilon_{a,t}$). (d) Housing sector productivity shock ($\varepsilon_{a_h,t}$). (e) Investment efficiency shock ($\varepsilon_{i,t}$). (f) MP shock ($\varepsilon_{R,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of aggregate welfare from its equilibrium value.

study. To the best of our knowledge, only a few studies examine how effective an MP rule adjusted for housing prices would be to various structural shocks under the LTV restrictions. Our empirical results are meaningful in that the housing-price-adjusted MP rule is found to

effectively stabilize the economy in response to a demand shock, which is not addressed in previous studies (Iacoviello & Neri, 2010).

Household debt has reached a record high and is considered one of the most serious problems faced by

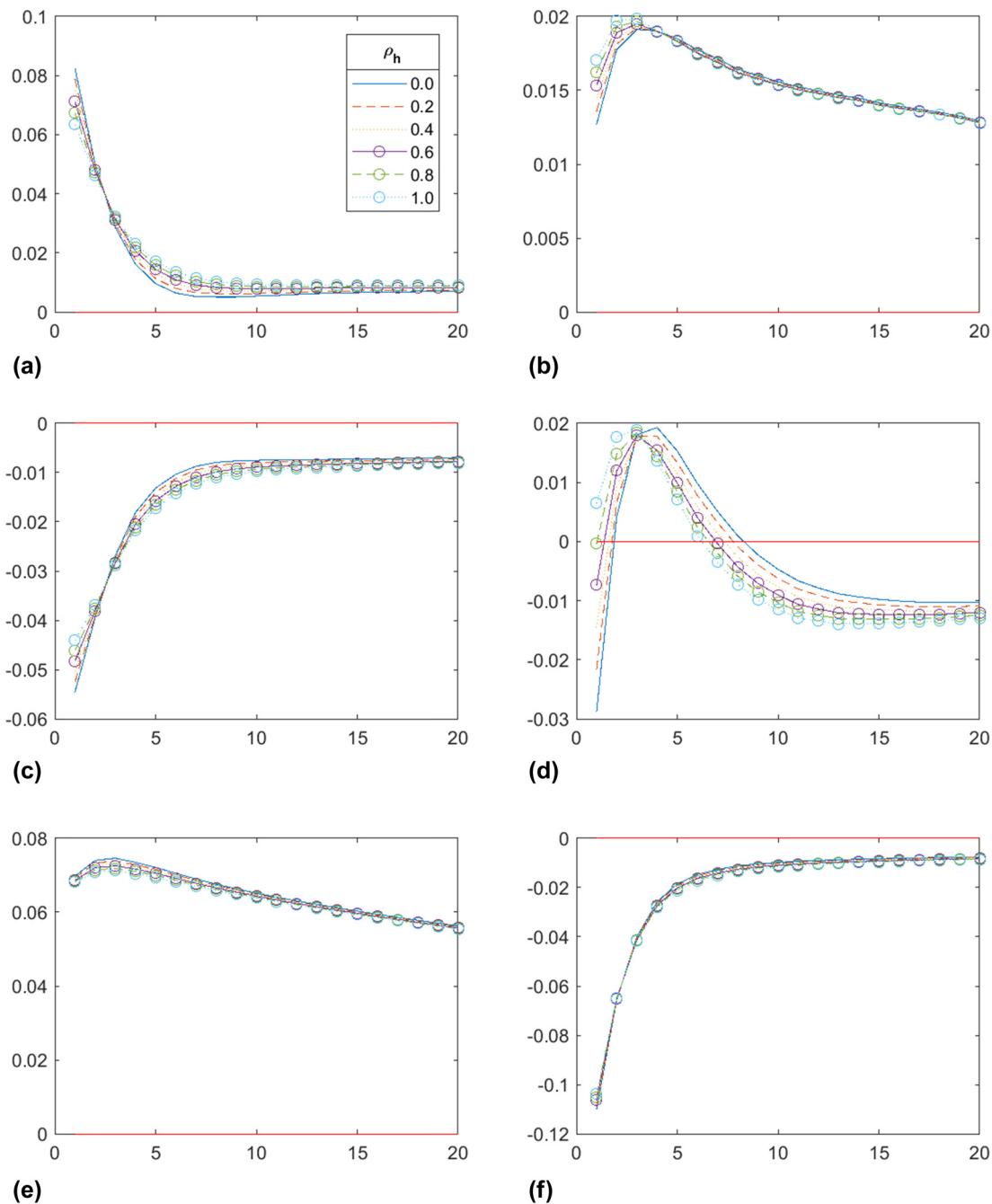


Figure 19: Aggregate welfare (W) response depending on the policy weight on housing prices (ρ_h). (a) Consumption preference shock ($\varepsilon_{c,t}$). (b) Housing preference shock ($\varepsilon_{h,t}$). (c) Non-housing sector productivity shock ($\varepsilon_{a,t}$). (d) Housing sector productivity shock ($\varepsilon_{a_h,t}$). (e) Investment efficiency shock ($\varepsilon_{i,t}$). (f) MP shock ($\varepsilon_{R,t}$). Note: The x-axis shows the quarter, and the y-axis shows the deviation of aggregate welfare from its equilibrium value.

the Korean economy. Both the level and the growth rate of debt are unprecedented, and the debt is highly concentrated in the housing market. Hence, concerns are growing that underperformance in the housing market will trigger deleveraging, which may debilitate the housing market and, eventually, the overall financial system. These

concerns should be assessed quantitatively to gauge their potential risk and determine the relevant policy measures.

This study constructs and estimates a DSGE model based on Korean data. Our model incorporates heterogeneous households with different subjective discount rates, collateral constraints, and a housing production sector.

Based on this model, we conduct comparative static analyses using various external shocks and analyze the effects of these shocks on output, consumption, general prices, housing production, interest rates, and housing prices relative to the baseline. In particular, we investigate a hypothetical scenario in which the LTV ceiling is set below its current level and the interest rate responds to housing price fluctuations in an otherwise standard MP rule.

The simulation results show that tighter LTV restrictions can reduce the influence of external shocks on the economy. As a lower LTV ceiling reduces the amount of debt that borrower households can afford, the deleveraging effect, which is mostly caused by borrowers' re-optimization, is alleviated relative to the baseline case. When the MP rule is adjusted to include housing prices in its reaction function, MP becomes more sensitive to housing price movements and tends to allow the housing market and the macroeconomy to stabilize more quickly than in the baseline case. For example, a negative housing preference shock lowers the interest rate directly to stabilize housing prices. As a result, the decrease in consumption and real GDP is smaller than in the baseline case, in which interest rates are adjusted indirectly through inflation and the output gap following a shock.

When the MP rule that incorporates the housing price gap is introduced in combination with a tighter LTV ceiling to mitigate the impact of deleveraging, any negative shocks to housing prices are countered by both lower interest rates and the decumulation of debts. The responses of real GDP, consumption, and investment to negative housing price shocks are more subdued compared to the cases in which policy adjustments to the housing price gap are not made.

Finally, we investigate the optimal MP rule with respect to ρ_{hh} , the MP response to the housing price. We find that the optimal policy is asymmetric depending on the source of the shock. In the case of a demand shock, a higher ρ_{hh} leads to higher aggregate welfare, whereas a lower ρ_{hh} is optimal in the case of a supply shock. This result suggests that the source of a housing price shock should be correctly identified and understood so that MP can achieve its intended objective. In sum, an LTV ceiling and asymmetric MP depending on the source of a housing price shock are effective policy tools to mitigate the potential risks from debt deleveraging.

Tightening LTV regulations restricts home buyers' lending limits, thereby restraining demand and either mitigating housing price rises or inducing price declines. However, tighter regulations can deprive households of homeownership if they lack sufficient cash. Thus, although tightening LTV regulations can improve macroeconomic

resiliency, different LTV ceilings for socially disadvantaged households and credit from public institutions should be provided in parallel.

Based on our analyses and findings, we suggest some future research topics. First, it would be interesting to include the dynamic processes by which macroeconomic variables fluctuate when the LTV ceiling changes from 70% to 50%. Doing so would require developing an entirely different set of dynamic models to track the transitions of macroeconomic variables over time. Second, a further investigation on the benefits/costs of LTV ceilings can reveal which households (i.e., borrowers or savers) would benefit from the restriction, potentially suggesting meaningful intuitions about the political economy feasibility of an LTV ceiling.

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